CAGE Scanner

Investigating Surface Backgrounds in HPGe Detectors for LEGEND

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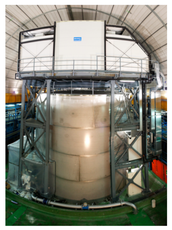
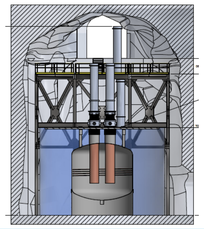
LEGEND The Large Enriched Germanium Experiment for Neutrinoless $\beta\beta$ Decay

Mission: "The collaboration aims to develop a phased, **Ge-76 based** double-beta decay experimental program with discovery potential at a **half-life beyond 10^{28} years, using existing resources as appropriate to expedite physics results**."



First phase:
- (up to) 200 kg in upgrade of existing infrastructure at LNGS
- BG goal: **<0.6 c /(FWMH t y)**
- Discovery sensitivity at a half-life of **10^{27} years**
- Data start ~2021

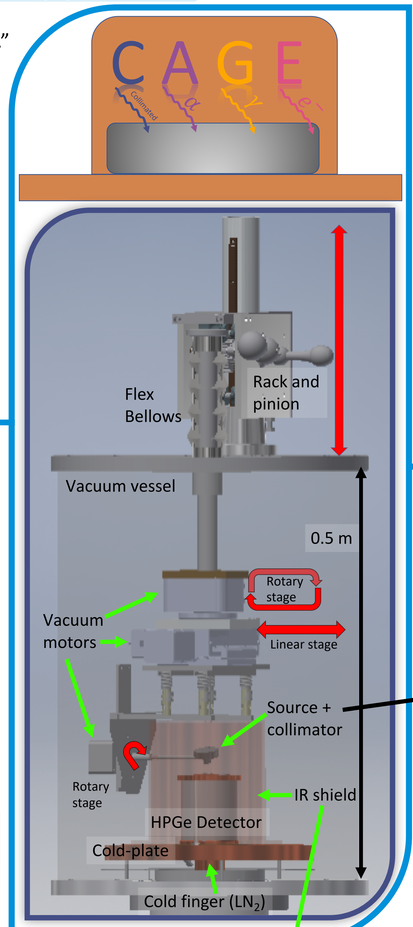


Subsequent stages:
- 1000 kg, staged via individual payloads
- Timeline connected to review process
- Background goal: **<0.03 cts/(FWHM t yr)**
- Location to be selected

48 Institutions, about 240 scientists

- University of New Mexico
- L'Aquila University and INFN
- Laboratori Nazionali del Gran Sasso
- University of Texas - Austin
- Tsinghua University, Beijing
- Lawrence Berkeley National Laboratory
- Univ. California Physics, Berkeley
- Univ. California Nuclear Engineering
- Leibniz Institute for Crystal Growth (IKZ Berlin)
- Comenius University
- University of North Carolina, Chapel Hill
- Sichuan University
- University of South Carolina
- Tennessee Tech University
- University of Warwick
- Jagiellonian University, Krakow
- Technical University - Dresden
- Joint Institute for Nuclear Research (Dubna)
- Duke University
- Triangle Universities Nuclear Laboratory
- Joint Research Centre, Geel
- Max Planck Institute - Heidelberg
- Queens University
- University of Tennessee
- Lancaster University
- University of Liverpool
- University College London
- Los Alamos National Laboratory
- Istituto Nazionale di Fisica Nucleare - Milano Bicocca
- Milano University and Milano INFN
- National Research Center Kurchatov Institute (NRC KI)
- Institute of Nuclear Research, Russian Academy of Sciences
- Laboratory for Experimental Nuclear Physics of MEPhI (Moscow Engineering and Physics Institute)
- Max Planck Institute - Munich
- Technical University - Munich
- Oak Ridge National Laboratory
- Padova University and Padova INFN
- Istituto Nazionale di Fisica Nucleare - Padova
- IEAP Czech Technical University in Prague
- North Carolina State University
- South Dakota School of Mines and Technology
- Roma Tre University and Roma Tre
- University of Washington
- University Tuebingen
- Academia Sinica, Taiwan
- University of South Dakot
- Williams College
- University of Zurich

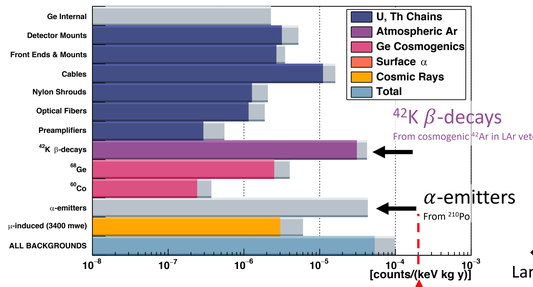
Collimated Alphas, Gammas & Electrons Scanner



Surface Backgrounds in LEGEND

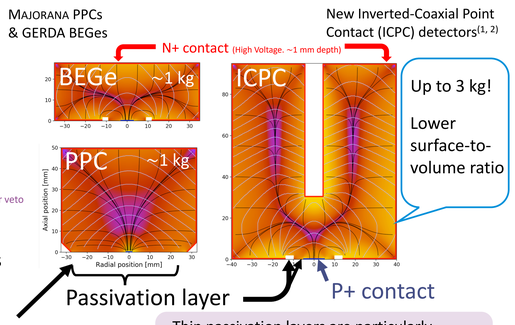
Shallowly-impinging α and β radiation on surfaces of detectors are energy-degraded from surface effects and can be reconstructed in the region of interest for neutrinoless $\beta\beta$ decay

Surface backgrounds dominate LEGEND-200 background projections!



(LEGEND-1000 background goal about 20x lower than LEGEND-200)

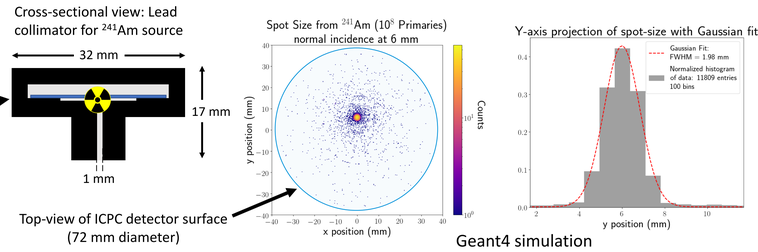
LEGEND Detector geometries



Thin passivation layers are particularly susceptible to surface backgrounds. CAGE will study these surfaces in detail.

Collimator and ^{241}Am spot-size simulations

To study surface effects, we are interested in the 5.5 MeV α and 60 keV γ from ^{241}Am



- With this collimator, we expect a spot size less than 2 mm for normal source incidence
- Spot size is still less than 3 mm for our most highly rotated scan (not pictured)
- We are able to achieve the required precision for detailed scans!

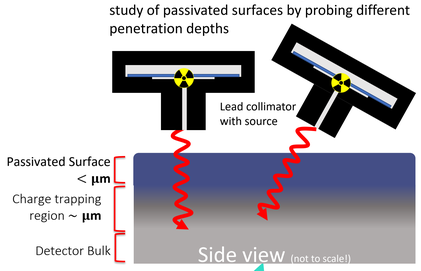
Scanning needs and goals

LEGEND has several test stands studying surface effects on HPGe detectors in vacuum. CAGE was developed to meet new needs for passivated surface studies in multiple detector geometries.

Needs:
- Avoid IR shine on passivated surfaces
- Freedom to move source beam to any location on passivated surfaces
- Vary incidence angle of source beam with respect to detector surface

CAGE Design:
- Collimator and source internal to IR shield
- Three-stage Motor assembly:
  - Collimator mounted on translatable, rotatable IR shield
  - Rotatable collimator + source

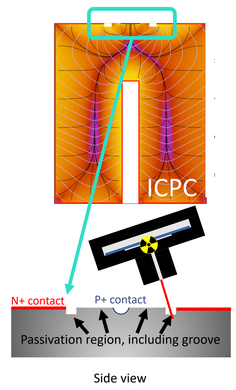
Scans at different incidence angles allow detailed study of passivated surfaces by probing different penetration depths

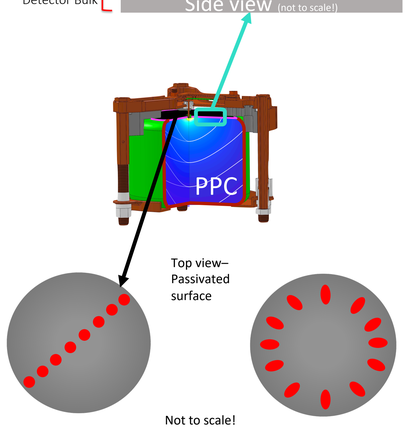


Scanning configurations

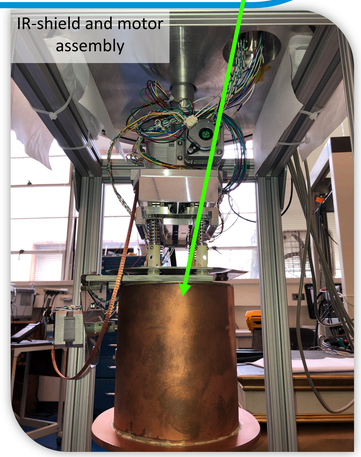
- Radial Scans with various incidence angles
- Azimuthal scans at various incidence angles
- Detailed scans of ICPC groove
- Allows for more information than fixed angle and fixed axis scans, enables model building for surface events

See video for demonstration of motor movement!



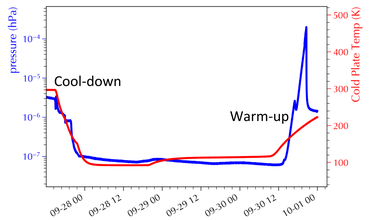


Detailed scans of ICPC groove | Radial Scans | Azimuthal Scans

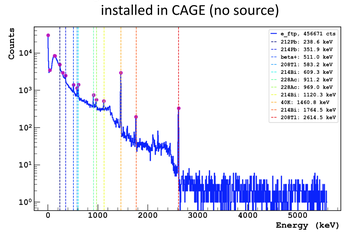


Commissioning, status, and future plans

First temperature cycling of CAGE cryostat



Background spectrum from PPC detector installed in CAGE (no source)



Commissioning status:
- Multiple successful tests of vacuum, cryogenics, and motor systems

Immediate next steps:
- ^{241}Am scan of ICPC detector when lab access granted (restricted due to COVID-19)
- ^{241}Am scan of PPC detector

Future:
- Develop specialized collimator and conduct scans with ^{90}Sr β source

References

1. R. Cooper et al., NIM A665, 25 (2011)
2. A. Domula et al., NIM A891, 106 (2018)

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